REMARKS

The non-final Office Action was issued on pending claims 1-3 and 5-19. Claims 1, 5-12 and 19 stand rejected. Claims 2, 3 and 13-18 stand withdrawn from consideration. In this Response, no claims have been amended, cancelled or added. Thus, claims 1, 5-12 and 19 are pending and under consideration.

Applicants invite the Examiner to call Applicants' Representative to discuss any issues with this application.

Specification Amendment

The previous Amendment submitted on July 1, 2003 included an amendment to the specification at page 35, lines 2-22. After reviewing that amendment, a typographical error was identified. The amendment to the Specification at page 35 submitted in this Response is merely to correct the typographical error. Applicants apologize for any inconvenience.

New Matter Objections and Rejections

At page 2 of the Office Action, the amendment to the specification submitted July 1, 2003 was objected to under 35 U.S.C. § 132 as containing new matter. At page 2 of the Office Action, claims 1, 5-12 and 19 were rejected under 35 U.S.C. § 112, first paragraph, as failing to comply with the written description requirement by containing new matter. Applicants respectfully disagree.

The specification objection and the claim rejections are based on the same assertion. The Office Action asserts that the opening width W of the plasma nozzle being set in the range of 10 mm $< W \leq$ 100 mm and more preferably set in the range of 10 mm $< W \leq$ 20 mm is new matter. However, those features of Applicants' invention are supported by the application as originally filed.

Applicants' invention pertains to an improved surface treatment apparatus for forming a film on a substrate. Applicants' surface treatment apparatus can provide a crystalline thin film of high quality at a high speed on the substrate. See Applicants' Specification at page 1, Field of the Invention section. According to one aspect of Applicants' invention, surface treatment of the

substrate is improved by generating hollow discharge plasma at a plasma nozzle. The density of plasma directed to the substrate is increased by the hollow discharge plasma at the plasma nozzle. See Applicants' Specification at page 11, line 16 - page 12, line 8 and page 8, line 23 - page 9, line 1. The hollow discharge generated by Applicants' invention allows for the surface treatment of the substrate to be accelerated and a high quality surface treatment can be maintained. See Applicants' Specification at page 12, lines 9-15.

According to certain embodiments of Applicants' invention, hollow discharge is generated when an opening width W of a plasma nozzle is set in the range satisfying either of $W \leq 5L(e)$ or $W \leq 20X$. L(e) is an electron mean free path in respect to atom or molecular species (active species) of the smallest diameter among raw material gas species and electrically neutral atom or molecular species (active species) produced therefrom by decomposition, under the desired plasma generation conditions, and X is a thickness of a sheath layer generated under the desired plasma generation conditions. Such range setting can make the plasma nozzle the hollow anode discharge generation area. See Applicants' Specification at page 34, lines 13-23 and page 35, lines 2-14. Furthermore, hollow discharge can be generated when the opening width W is set in a range satisfying $X/20 \leq W$, and also in a range satisfying $X/5 \leq W$. See Applicants' Specification at page 34, line 23 - page 35, line 1 and page 35, lines 14-17. Applicants' Specification further provides at least two examples of ranges of sizes of the diameter of a recess for generating hollow discharge. A diameter in the range of 1 to 100 mm and a diameter in the range of 1 to 20 mm provides hollow discharge generation. See Applicants' Specification at page 35, lines 17-22.

Applicants' Specification as originally filed teaches an objective of providing hollow discharge to improve the surface treatment of the substrate. Applicants' Specification as originally filed further teaches examples of numerical ranges for the diameter of recesses or nozzles to generate hollow discharge for improving surface treatment of the substrate. Applicants respectfully submit that one of ordinary skill in the art having the benefit of Applicants' teachings would understand that a recess/nozzle diameter in the range of 1 to 100 mm would advantageously produce hollow discharge. Amended claim 1 and amended page 35 of the Specification describe the range of an opening width to generate hollow discharge to be set at $10 \text{ mm} < W \leq 100 \text{ mm}$. Clearly, the lower end of the range at 10 mm is within the range of 1

to 100 mm for generating hollow discharge as taught by the application as originally filed. Thus, the 10 mm size is supported by the application as filed and is not new matter.

Furthermore, there is a particular advantageous working-effect for setting the opening width of the nozzle in a range satisfying $10 \text{ mm} < W(1) \leq 100 \text{ mm}$.

There is a plasma sheath layer, in which ions having a plus charge cannot exist, around the high-frequency electrode. Therefore, in order to excite high-density hollow plasma, the diameter of the nozzle should have at least a size twice that of the thickness of the sheath layer. In the case of the high-frequency excitation plasma, the thickness of the sheath layer is about 2 to 3 mm in 13.56 MHz of RF and about 0.5 to 1 mm in 100 MHz of VHF.

Thus, the lower limit of the diameter of the nozzle in this application, when the margin is 50%, is about 10 mm in the RF region and about 3 mm in the VHF region. Fig. 1 below shows an experimental result of the nozzle diameter relationship to excitation of hollow plasma. When the nozzle diameter is 5 mm, hollow discharge is not excited (Fig. 1a below), and it is clear that discharge is excited when the diameter is 13 mm (Fig. 1b below). Similarly, the nozzle diameter of more than 10 mm has a characteristic and particular advantageous working-effect according to the used power supply frequency.

Meanwhile, the thickness of the sheath layer is described by electron temperature, electron density and space potential of plasma (see the expressions below) and hardly relies on gas pressure or high frequency power. Further, with increasing the frequency, the nozzle diameter of more than 1 mm, as mentioned in the original specification, can excite the hollow plasma.

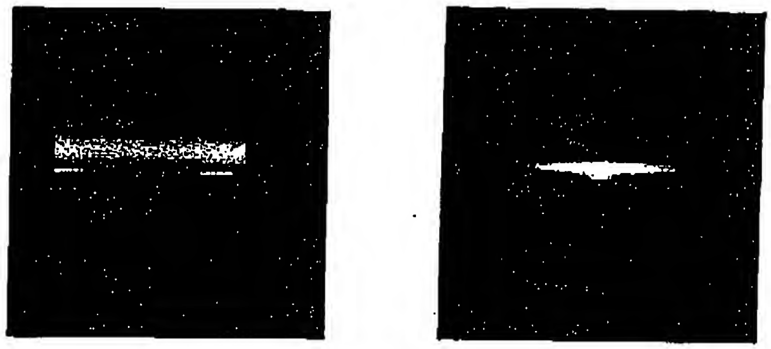
[Thickness of Sheath]

When approximating parallel plate electrode, the following expression is obtained.

$$0.97\left(\frac{d}{\lambda_D}\right)^2 = \left(\frac{eV_p}{kT_e} - \frac{1}{2}\right)^{3/2}$$

Note, however, the following.
d: thickness of sheath (cm)
Te: electron temperature (eV)
λ_D : Debye length= $\sqrt{\varepsilon_0 kT_e / N_e e^2}$ (cm) . ··· (1)
Vp: plasma space potential(V)

[Fig. 1] Relation between Nozzle Diameter and Generation of Hollow Plasma



(a) Nozzle Diameter=5mm (b) Nozzle Diameter=13mm

Conditions: RE Frequency = 13.56MHz, RF Power =75W, Pressure =0.4 Torr

Thus, setting the nozzle opening width in a range of 10 mm < w(1) ≤ 100 mm, as taught by Applicants' application, provides the advantage of generating hollow plasma, which is an objective of the present invention.

CONCLUSION

For the foregoing reasons, Applicants submit that the patent application is in condition for allowance and request a Notice of Allowance be issued.

Respectfully submitted,

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